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GROUNDWATER MODELLING USING FDM IN CHAKSU REGION, JAIPUR, INDIA

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ABSTRACT

Groundwater is the major source of freshwater being utilized by domestic, industrial and agriculture sectors worldwide. The present developmental activities have put pressure on the groundwater and the results are in the form of depleting groundwater level and deteriorating quality. Quantitative assessments of groundwater resources and their vulnerability to adverse natural and anthropogenic impacts require conceptualization, quantification and modelling of often vast, complex and heterogeneous groundwater systems with inclusion of various physical, geochemical and biological processes. Therefore, there is a growing need for practical, cost-effective methods of groundwater systems characterization that could be applied in the real-world management of groundwater resources. Groundwater modeling can be defined as the quantification and simulation of the natural movement of groundwater through any porous or fissured media. MODFLOW has a modular structure that allows it to be modified to adapt the code for special applications. It simulates steady and transient flow in an irregularly shaped flow system in which aquifer layers can be confined, unconfined, or a combination of confined and unconfined.

KEYWORDS: Groundwater, Groundwater Modelling, MODFLOW, Simulation

INTRODUCTION

Groundwater is the most preferred source of water for different users in India on account of its near universal availability, dependability and low capital cost. Ground water has made significant contributions to the growth of India's Economy and has been an important catalyst for its socio economic development. The ground water behavior in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. Groundwater models usually replicate the groundwater flow process at the targeted site of interest and can be used to complement monitoring studies in evaluating and forecasting groundwater flow and transport. The model can be physical (a laboratory sand pack), electrical analog or mathematical [1]. The conceptual model is base for mathematical modelling. The mathematical model can then be solved in two ways: either analytically [2] or numerically [3].

Once the conceptual model is translated into a mathematical model in the form of governing equations, with associated boundary and initial conditions, a solution can be obtained by transforming it into a numerical model or analytical model and writing a computer program (code) for solving it using a digital computer. The groundwater modeling process is summarized in Figure 1.

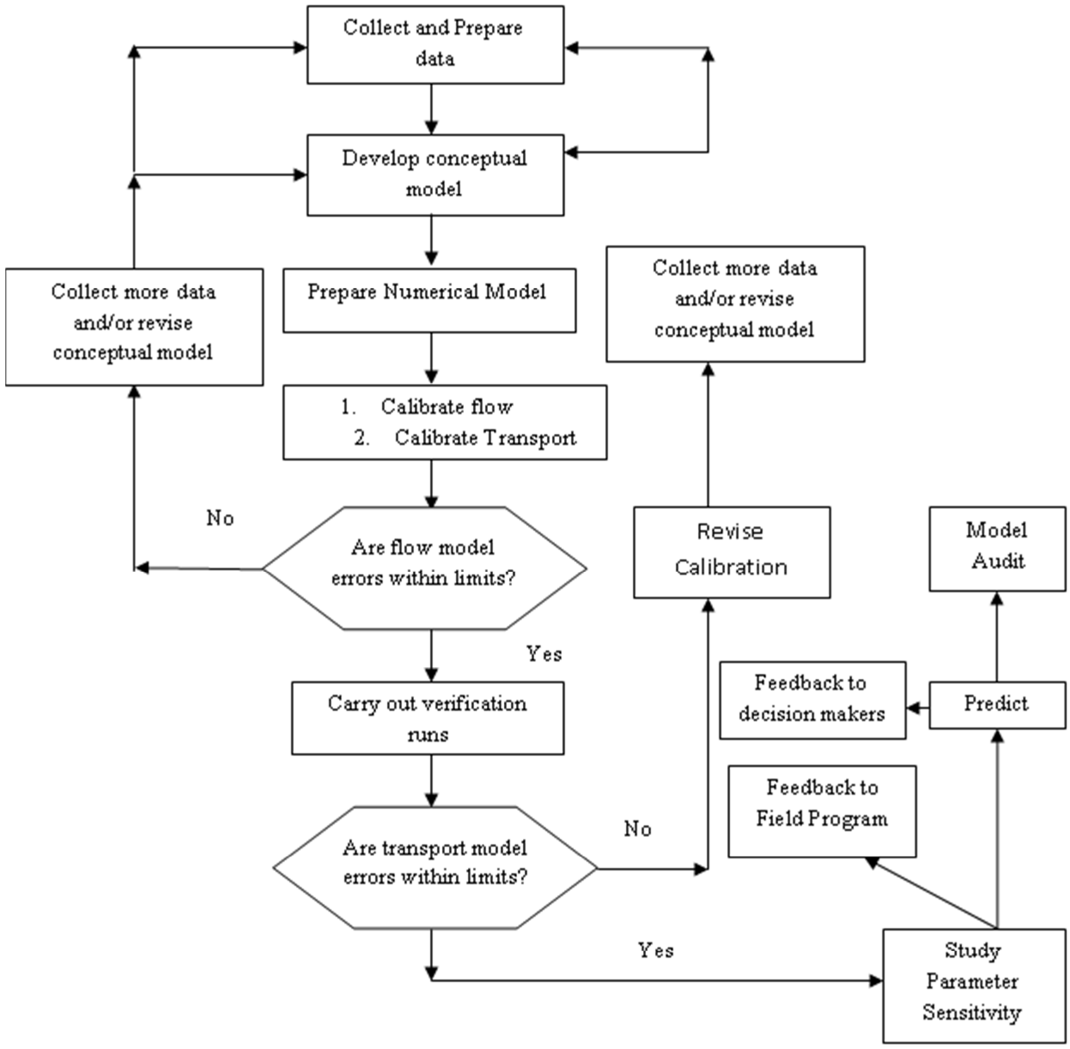

Figure 1: The Groundwater Modeling Process

LITERATURE REVIEW

A groundwater model approximately simulates the input and output stress and system's response relation.[3-5] The most used techniques in groundwater modelling are finite element method [6-9], analytical element method [10], and finite difference method [11-13]. Hydrogeological characterization for aquifer recharge studies have also been illustrated by Sinha and Scanlon et al [14-15].

Finite element simulation of phreatic flow domain using recharge distribution coefficients was done by Sulekha and Rastogi [16]. They have carried out recharge from rainfall, seepage from canal and irrigation return flow over normal input to lager aquifer system. Basin wise water balance modelling with emphasis on spatial distribution of groundwater recharge was done by Sophocleous and McAllister [17]. Dehotin et al. created a 2D groundwater model to handle vertical and horizontal aquifer heterogeneities [18]. Atilla developed a transient groundwater flow model for the confined aquifer under the Afyon Plain in Turkey [19]. The spatial and temporal extent of hydraulic head over the plain was simulated using MODFLOW. Ayenew, Demlie & Wohnlich conducted a numerical modeling study for the groundwater system in the Akaki catchment of central Ethiopia [20].

STUDY AREA

The study area is Chaksu Tehsil of Jaipur district in Rajasthan. It mainly covers the southern part of the Jaipur district falling under the Survey of India Toposheetnos 45N/13; 45N/14 and 54-B/2. The geo-coordinate of the Chaksuare 26°36′N latitude to 75°57′E longitude. Geomorphologically, the region has alluvial plains while geologically, the area has rocks of Archaean age and blown sand. The main river in the block is Dhund River. The Important aspect of the study area is that it falls in subcatchment zone of Morel river which is ephemeral in character. The region is in close proximity of Jaipur city and is suffering from depleting groundwater level and deteriorating groundwater quality. Figure 2 depicts the potential groundwater zone and aquifer of Chaksu region.

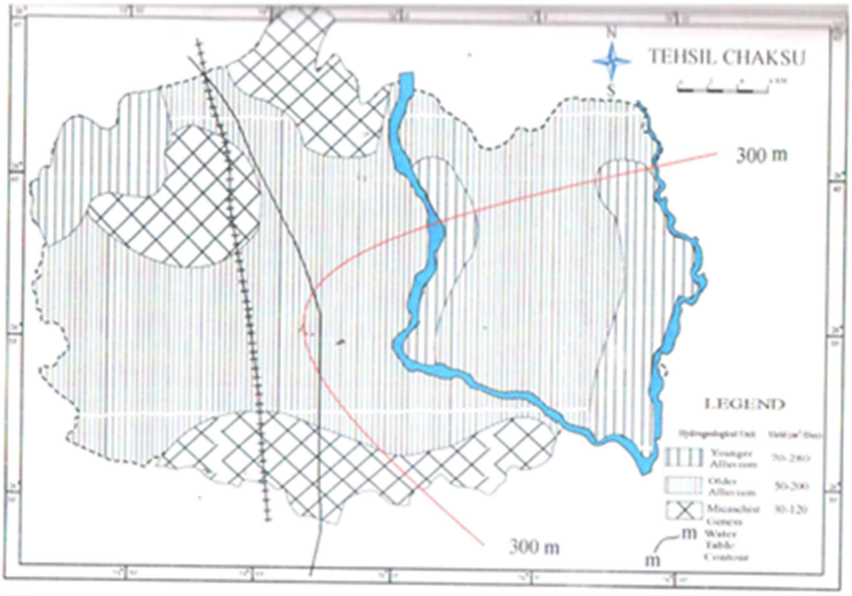

Figure 2: Groundwater Potential Zone and Aquifer (Chaksuregion)

MODEL SETUP OF THE STUDY AREA

Three dimensional finite difference groundwater flow model was designed and constructed with visual MODFLOW[21]. The grid network size can be selected conveniently depending on the objective of the modeling process, available data, elements of the conceptual model, and modeler'sexperience [22]. The model consisted of a single layer representing the alluvium unit. The layer type was specified as unconfined. As such, the hydraulic conductivity and storability of the layer waskept constant throughout the simulation. The regional hydro-geologic framework of Chaksu Watershed has been defined by a model grid consisting of 40 columns, 38 rows, and 1 vertical layer. Each cell has dimensions of 1871 m by 1476 m, resulting in a total of 1520 cells. Figure 3 shows the model design and discretization.

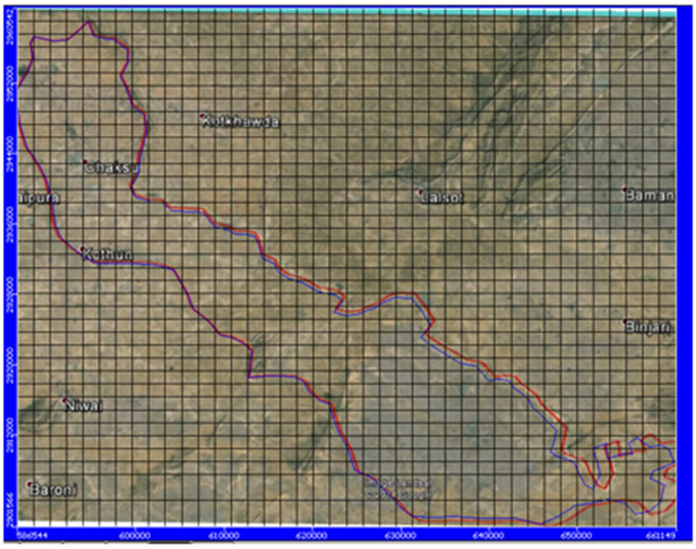

Figure 3: Model Design and Discretization

Head values for cells representing the water table was derived from the water level data. The pre and post monsoon water level data of 222 wells Chaksu block were collected from CGWB (Central Ground Water Board, Govt. of India).This data were then adapted to the model grid (Figure 3) and conceptual model. The spatial distributions of horizontal hydraulic conductivity within model layers was determined by gridding observations and estimates of K, spatial averaging of results into zones of similar K values. Table 1 depicts the temporal change in water level.

Table 1: Temporal Change in Water Level (CGWB, 2007)

Block	Average Water Level 1984 (m)	Average Water Level 1996 (m)	Average Water Level 2001 (m)	Average Water Level 2006 (m)	Average Water Level Fluctuation Pre-Post 2006	Average Rate of Water Level Decline 1984-2006 (m/yr)	Average Rate of Water Level Decline 1996-2006 (m/yr)	Average Rate of Water Level Decline 2001-2006 (m/yr)
Chaksu	9.62	11.85	13.58	22.73	1.60	0.60	1.09	1.83

The boundary conditions are an important part for the conceptualization of the groundwater flow system [23-24]. The area is underlain by hydro - stratigraphic units, namely an upper unconsolidated zone and a lower fractured rock zone. The groundwater is recharged from rainfall. The ground water flow follows the topography and flows from north-western boundary of the model area towards south- easterly direction. Accordingly, these have been simulated as constant head boundaries in the model. Groundwater outflow from study area takes place from south-eastern boundary. Groundwater contours are widely spaced and indicates presence of porous aquifer. Rest of the boundary is designated as no flow boundary on the basis of groundwater flow analysis.

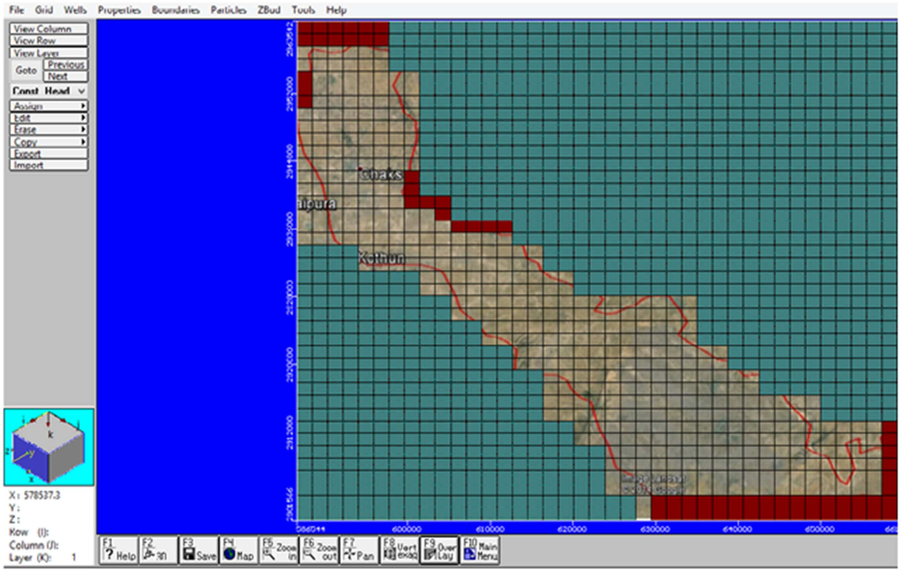

Figure 4: Map showing Boundary Conditions

WATER BUDGET CALCULATION

Results of water-budget calculations (Table 2) indicate that there is significant inflow to the alluvium aquifer from the constant-head boundary. Water-budget calculations also show that a majority of this flow exits the model through constant-head nodes, which is consistent with the conceptual model for the area.

Table 2: Water Balance of the Model Area

Flow Component	2013	2025	2050
	(m^3/Year)	(m^3/Year)	(m^3/Year)
Net Inflow from surrounding area	127,46,909	118,85,680	134,22,992
Recharge Inflow	931,12,512	931,67,504	925,07,520
Total Inflow	1058,59,421	**1050,53,184**	**1059,30,512**
Pumping Outflow	36865000	438,00,000	558,01,200
Net Outflow to surrounding area	68994424	612,53,132	501,29,304
Total Outflow	**1058,59,424**	**1050,53,132**	**1059,30,504**
Total In flow - Total Outflow	-3	52	8

CALIBRATION AND VALIDATION OF THE MODEL

A steady-state calibration is accomplished for the year 2001. The general groundwater flow direction is from north- west to south east. The computed and observed water levels during steady state are shown in Figure 5. The calibrated steady-state model conditions have been used as initial conditions for the transient model.

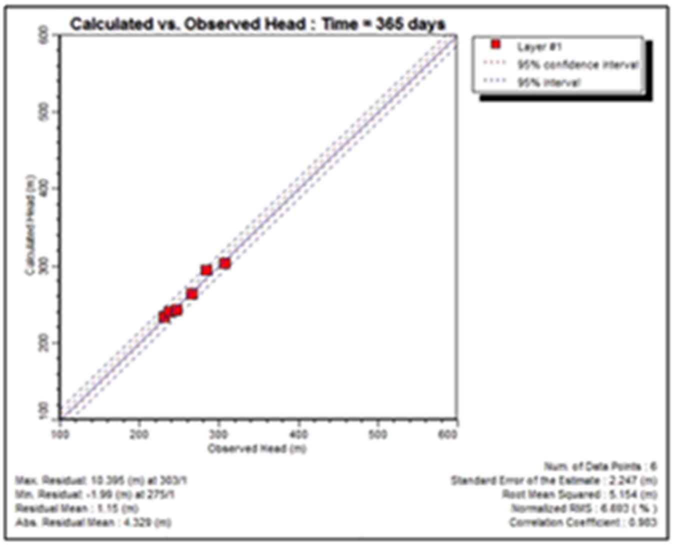

Figure 5: Simulated and Measured Water Levels (Steady State)

MODEL FORECASTS

It is projected that the demand for public water supply and irrigation demand in the Chaksu study area will increase by approximately 30 percent between 2013 and 2050. To understand how this increased pumping may affect groundwater flow and water budgets, we assumed that this increased demand will be supplied by existing wells and simulated the increased water demand by increasing concurrently the pumping rate for all current irrigation wells by 30 percent. Comparison of predicted water levels during increased pumping to previous model-simulated results indicates that the maximum head decline in the Alluvium aquifer will be approximately 2.5 meters by 2050 (Figure 6 & 7). The maximum head decline (about 4 meters) is in northern part of model area.

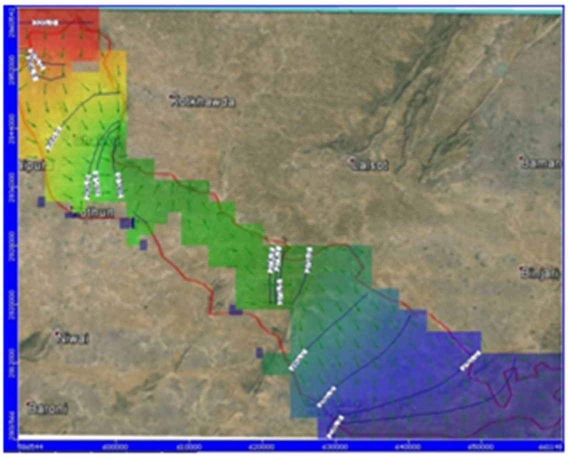

Figure 6: Observed Head in 2013

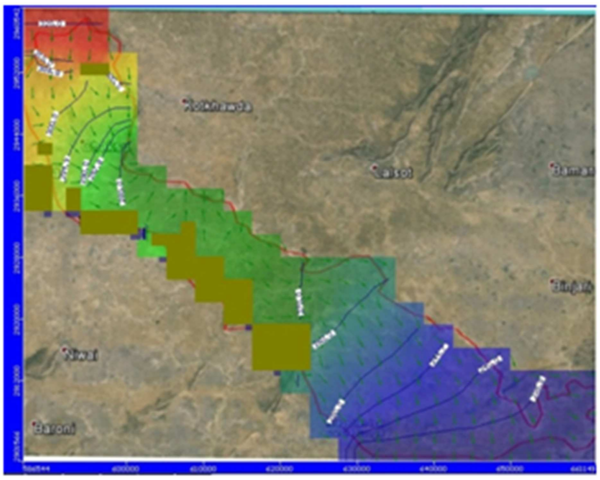

Figure 7: Model Computed Head in 2050

CONCLUSIONS

The purpose of this work was to understand groundwater flow and groundwater levels due to pumping, predict changes in flow and groundwater levels due to changes in pumping, and evaluate the completeness and suitability of existing hydro geological data. The groundwater flow modelling results reveals that the general flow of groundwater isfrom north-west to south-east direction. The groundwater recharge area has been identified in north – western boundary.Contour maps of head indicate that the majority of water is leaving the model domain along the southern boundary of the model area. Water use efficiency awareness among farmer will reduce groundwater abstraction thereby arrest the rapid decline of groundwater. Drip irrigation needs to be encouraged among farmer along with subsidy and suitable incentive.Participatory approach for groundwater management with involvement of voluntary organization and stakeholders will help in better management of groundwater resources.

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